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Delineation of Artificial Recharge Zones Using Geospatial Techniques In Sarabanga Sub Basin Cauvery River, Tamil Nadu

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Abstract

A case study has been conducted to delineation of artificial recharge zones using geospatial techniques in Sarabanga sub basin Cauvery River, Tamil Nadu. The groundwater storage change from place to place and there isneed to identify recharge zones throughgeospatial technology as an important strategy for water management system.However conventional methods alone it is not an easy task to study the surface parameters of a large area to identify suitable sites for artificial recharge, since many controlling parameters must be independently derived and integrated, which involves additional cost, time and manpower. Modern remote sensing technologies have many advantages over older, conventional methods due to their synoptic coverage, improved spatial resolution, and their capabilities for multi-spectral and multi-temporal analysis. In addition, unlike conventional methods for demarcation of suitable areas for groundwater replenishment are able to take into account the diversity of factors that control groundwater recharge. Based on the GIS overlay analysis the possible combinations for recharge sites based on geology, geomorphology, lineament, lineament density, drainage density, Landuse and Landcover combinations covers an area of 915.052 Sq.kmand are suitable for various artificial recharge structures. The results show that by expanding the artificial recharge system, the recharge volume can be increased even for small flood events.

Keywords: Geospatial Techniques; Lithology; Artificial Recharge; Geology; Geomorphology; subtract;

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1. Introduction

Artificial recharging is the planned, human activity of augmenting the amount of groundwater available through works designed to increase the natural replenishment or percolation of surface waters into groundwater aquifers, resulting in a corresponding increase in the amount of groundwater available for abstraction. In India, this method has been in use for quite some time and its historical evolution is briefly outlined. It has been used for many beneficial purposes although the primary objective of this technology is to preserve or enhance groundwater resources. A variety of methods developed and applied to artificially recharge groundwater both in the urban and rural sectors have been reviewed. Various artificial recharge experiments have been carried out in India by different organizations, and have established the technical feasibility of the artificial recharge of unconfined, semi-confined and confined aquifer systems. The studies on artificial recharge techniques are mostly site-specific and descriptive in nature, which gives little insight into the potential success of implementing this technology in other locations.Many assessments of groundwater conditions made with remote sensing techniques have been reported (Krishnamurthy and Srinivas 1995; Bastiaansen et al. 1998; Venkata et al.2008; Chowdary et al. 2009; Jasrotia et al. 2009). Geographic Information System (GIS) techniques have many advantages over older, improved georeferenced thematic map analysis and interpretations (Thapinta and Hudak 2003; Dixon 2005; Martin et al. 2005). Cowen (1988) defined GIS as a decision support system involving the integration of spatially referenced data in a problem solving environment. In addition, unlike conventional methods, GIS methods for demarcation of suitable areas for groundwater replenishment are able to take into account the diversity of factors that control groundwater recharge. Thematic map integrated various features derived from data in a GIS environment (Krishnamurthy et al. 1996; Murthy 2000; Saraf and Choudhury 1998; Baker et al. 2001; Henry et al. 2007; Tabesh et al. 2009). However only a limited number of studies have taken the approach of specifically mapping potential artificial recharge zones, and as such there is no integrating of multi-criteria analysis using the weighted aggregation method, associated with GIS techniques to derive the groundwater recharge map. It is a new approach adopted for mapping groundwater recharge zones.In recent years, a shift in groundwater resources management approaches from the traditional concept towards the new model using the geographical information system utilities can be recognized (Rowshon et al. 2009; Koch and Grünewald 2009; Al-Qudah and Abu-Jaber 2009). The GIS techniques applications in hydrogeological mapping can be almost divided into two parts: hydrological analysis (Patil et al. 2008; Naik et al. 2009) and water resources development (Wu et al. 2008; Chowdary et al. 2009) on the one hand and water quality (Mantzafleri et al. 2009) on the other.

2. Study area

Sarabanga sub basin located between north latitudes 11°46’00’’ to 12°09’39” and east longitudes 78°12’27” to 78°36’65” (1178.56 km^2 in area) is laying entirely in the Salem district of Tamil Nadu state, India. Out of the total area, around 715.70 km^2 is covered with forest, 159.69 km^2 with agriculture, and 19.81 km^2 with water bodies. River Sarabanga and its tributaries are the major water sources of this study area. Itcover in an areal extent of 1178.56 km^2 and fell entirely in the Salem district. Sarabanga river originate on the western slope of Shevaroy hills at an altitude of 1630 m amsl, it’s appears only rainy seasons, people in this region entirely depends on the groundwater resources for their domestic, agricultural and industrial needs. ClimatologicallySarabanga sub basin is hot and semiarid and receives an average annual rainfall of 852 mm (2000-2009) out of which 90 % is received during the southwest (June-Sept) and the northeast (Oct-Dec) monsoon periods and the hot weather begins early in March, the highest temperature being reached in April and May. Weather cools down progressively from about the middle of June and by December, the mean daily maximum temperature drops to 30.2°c, while the mean daily minimum drops to 19.2°c and 19.6°c. The sub basin and its parts are easily approachable by metalled road from any part of the state. (Fig.1)

3. Materials and methods

The multiple parameter analysis for delineating the artificial groundwater recharge sites in the study area has been done by Geospatial technique. In this study, 9 spatial parameters such as geology, geomorphology, slope, land use and land cover, lineament density, drainage density, soil, aquifer thickness and rainfall are analyzed to construct various types of artificial recharge structures and give relevant weightages of different influenced parameter to explore the potential zone for groundwater recharge. For micro level study, 202 village maps were scanned and

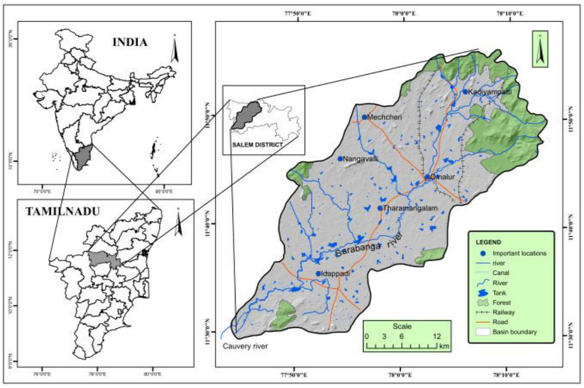

Fig.1.Location of the study area

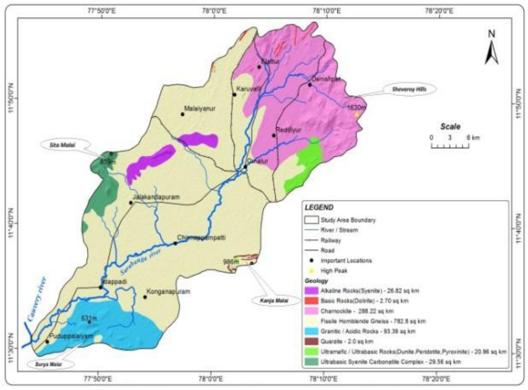

Fig.2.Geology of the study area

digitized in GIS environment with attributes (Village index numbers).

4. Data collection and preparation of geospatial database

Nine spatial parameters have been used for geospatial database preparation. Using Geospatial techniques, the thematic layers namely geology, geomorphology, slope, land use and land cover, lineament density, drainage density, soil, aquifer thickness and rainfall were prepared from the above data sources and projected with UTM–WGS 84 projection and coordinate system. The geological thematic layer was prepared from the published map of Geological Survey of India using digitizing technique in ArcGIS 10.1 environment. Similarly, the soil maps have been prepared from soil survey of India. Moreover, the slope map was prepared using SRTM data and the drainage density map was prepared from the Survey of India topographical map. The geomorphology and lineament density layer has been prepared from Landsat IRS P6 LISS IV image using visual interpretation technique and Landuse/land cover map was prepared using supervised classification method in Erdas Imagine 9.1 software. The average annual average rainfall map has been prepared from the rain gauge data collected from Indian Meteorological Department for the year 2002-2011. The attribute database of these different layers of various recharge methods are using weighted overlay index the suitable area to construct artificial recharge structures are recommended.

5. Assignment of weight to parameters

In the present study, the Geospatial technique was applied to integrate different thematic layers based on the assigned weights for suitable site selection. Here, the weight of the feature class of individual parameter was assigned at a scale of 1–10 as per the guidelines of Central Ground Water Board, Government of India (CGWB, 2007). Further, the feature classes of each parameters were quantitatively weighted as poor (weight=1–3), moderate (weight=3–5), high (weight=5–7), and very high (weight=7–9). For example, the layer that has aquifer and more permeable soil type with agricultural land is assigned with the weight as 7, as well as the layer with hard rock with less soil depth and poor permeability is assigned as 1. Similarly, all parameters were assigned with a suitable weight and assigned weightage are given in Table 1.

6. Results and discussion

The potential zones for groundwater recharge were explored by analyzing the different parameters such as geology, geomorphology, slope, land use and land cover, lineament density, drainage density, soil, aquifer thickness and rainfall through integrated geospatial technology.

7. Geology

The study area is mainly underlined by Fissile hornblende biotite gneisses followed by charnockite and granite etc. Fissile hornblende biotite gneisses are the dominant group of rocks covering major parts of the study area. The minor amount of alkaline rocks (syenite) and basic rocks (dolerite) are noticed in south and northeastern part. The younger alluvium formations are seen predominantly in the central part of the study area and are considered as highly permeable. Besides that, the southwest parts of the study area consist of fluvial deposits, which are laid on hornblende biotite gneiss and are considered as good zone for groundwater recharge. However, the hard rock materials composed of crystalline charnockite and quartzite vein present in the southern part of the study and it's not suitable for groundwater recharge (Fig. 2).

8. Aquifer Thickness

Aquifers are water-bearing unconsolidated layer of geological structure of an area. The aquifer thickness is the groundwater storage from the unit of area. The sub surface layer thickness is highly varied place to place. Based on Vertical Electrical Sounding was carried out at 93 locations using Schlumberger configuration with electrode spacing of 150 m to demarcate different layers of aquifers are classified in to low thickness (<19.86), medium thickness (19.86-38.76), high thickness (38.76-60.76) and very high thickness (>60.76) the groundwater potential of the study area.

Table 1.Assignment of weight for the feature classes of individual parameter

Name of parameter	Feature class	Assigned Weight(AW)	Name of parameter	Feature class	Assigned Weight(AW)
Slope (in percentage)	0-1%	7	Soil		
	1-3%	6		Alfisols	6
	3-5%	5		Entisols	5
	5-10%	4		Inceptisols	4
	10-15%	3		Vertisols Miscellaneous Reserve	3
	15-30%	2		Forest	2
	>30%	1			
Aquifer Thickness			Land use/land \cover	Crop land	7
				Fallow land	6
	<40	7		Land with scrub	5
	40-66	5		Land without scrub	4
	66-86	3		Barren Rocky/ Stony Waste	3
	>86	1		Buildup Land	2
				Forest	1
Annual rainfall (in mm)			Geology	Alkaline rocks-Syenite	4
				Basic rocks-Dolerite	3
	<233	1		Charnockite	5
	233-237	3		Fissile Hornblende Biotite Gneiss	6
	237-266	5		Granitic/Acidic rocks	3
	>266	7		Ultrabasic SyeniteCarbonatite Complex	2
				Ultramafic / Ultrabasic rocks	3

The thickness of the weathered, fractured zone and depth to bed rock were determined from VES data. Due to over exploitation of groundwater in the study area, only fractured layers act as aquifers. Therefore the thickness of fractured zone was taken into ArcGIS platform. It is well known that storage increases with the thickness of the aquifer. Therefore the higher thickness of the aquifer, the more is the storage and vise versa. Similar areas are found in flood plain and debris wash plain in and northeast part and gentle slope surface in northeast and southeast part of the study area. These areas are mainly prepared for the construction of artificial recharge structures to groundwater replenishment. The moderate amount of groundwater potential is observed in the low thickness area along river channel (Fig.3).

9. Land use and land cover

Land use/land cover is one of the major controlling factors in groundwater recharge processes. The term land use relates to the human activity associated with a specific piece of land, while land cover relates to the type of features present on the surface of the earth. Urban buildings, lakes, residual hills, rocky out crop are all examples of land cover types. Agricultural, afforestation, and mining activities are a few land use categories in the study area.The different types of land use/land cover present in the study area are crop land, plantations, land with shrubs, land without shrubs, buildup land, forest, and water bodies shown in Fig.4 and IRS P6 LISS IV image shown in Fig.5. The forest land cover and plantation are present predominantly in the hilly terrains in southern, northeastern and northwestern part of the study area. These land use types are not suitable for groundwater recharge due to utmost availability of heavy rainfall. The land uses such as crop land, fallow land, land with shrubs and land without shrubs are found in the southern part of the study area.These areas are prioritized first for groundwater recharge because of less availability of both surface and groundwater for domestic and irrigation purpose.

9. Artificial recharge

The practice of artificial recharging is increasingly emerging as a powerful tool in water resource management. i. Infiltration Basin Method, ii. Ditch and Furrow Method iii.Flooding Method, iv. Irrigation Method, and v. Desilting of Existing Tanks is some popular artificial recharge structures are implemented in the study area. By constructing suitable types of artificial recharge structures, groundwater resources can be augmented.

10. Weighted Index Overlay Analysis:

Weighted Index Overlay Analysis (WIOA) is a simple and straight forward method for a combined analysis of multi class maps. The efficacy of this method lies in that the human judgment can be incorporated in the analysis.A weight represents the relative importance of a parameter vis-a-vis the objective. WIOA method takesinto consideration the relative importance of the parameters and the classes pertaining to each parameter. There isno standard scale for a simple weighted overlay method. For this purpose, criteria for the analysis are defined and each parameter is assigned importance (Saraf and Choudhury, 1998). The present study was been extended further to combine the surfaces created for groundwater quantity parameters such as rainfall, water level, geophysics, geochemistry geology, geomorphology and soil to generate groundwater quantity and quality data of the study area. The idea was to get a scenario that represents the overall situation of the area in context of above parameters at a particular time. In order to have the resultant groundwater information, the surfaces created for three parameters (Very Good, Good, Medium. Poor) were used as input theme for the weighted layers. Weighted overlay analysis technique was used to generate various thematic maps and get useful information in short time.

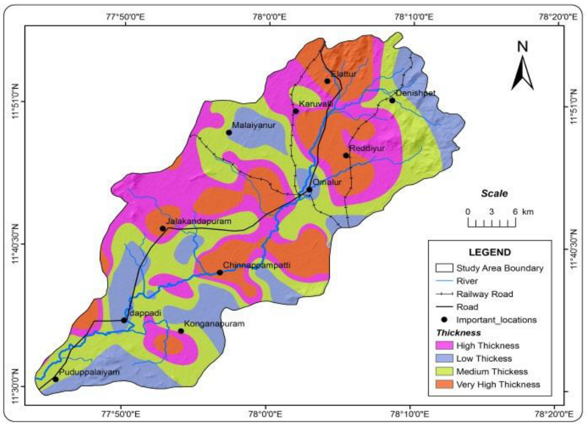

Fig.3.Aquifer thickness of the study area

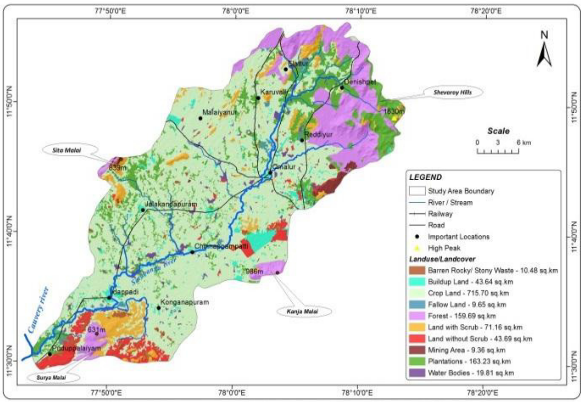

Fig.4.Landuse/Land cover of the study area

10.1. Infiltration Basin Method

Infiltration basins require a substantial amount of land area with a suitable geology, allowing the water to infiltrate into the aquifer and percolate to the groundwater table. It is simple to maintain and regular restoration of infiltration capacity and removal of clogging layers is relatively easy though time consuming. This method also allows for natural, quality improving processes to take place in the infiltration ponds and sub soil.For this method, the streams were taken as the best location for recharge. 67.92 km length of the stream falls as best recharge drainage for this method. 633 stream locations have been found suitable for the construction of artificial recharge structures shown in Fig.6. 54 (11 Villages) out of 629 (43 Villages) stream location areas had been identified as the most suitable sites while rest of the 577 locations had been classified moderate category and 119 villages had been identified as the best locations for Infiltration basin method.

10.2. Ditch and Furrow Method

The ditches may be dug sub parallel to the contours to draw water at an upstream point of the contours and return surplus water to the stream at a downstream point. In areas of irregular topography, shallow, flat bottomed and closely spaced ditches or furrows provide maximum water contact area for recharge from source stream or canal. It is suitable for irregular areas where slopes are too steep for basin construction shown in Fig.7. Low check dams and dykes can be constructed across a stream where a wide bottom occurs. For the selection of site by Ditch and Furrow method the following maps such as Drainage map, Land use/Land cover map, Topsoil, Weathered Zone and Fracture Zone Thickness Maps and Slope map were considered. In particular method 76 stream location areas had been identified as the most suitable sites in 21 villages of the study area.

10.3. Flooding Method

Flooding method involves inundating agricultural or waste lands with a thin sheet of water to a depth of a few centimeters to one meter depending on the nature of the terrain. This method is more suitable for relatively flat terrains. The land use and land cover, slope, soil permeability and soil thickness maps were used for identifying areas suitable for flooding method.The GIS output results have been given in Table 2 and village overlay map in Fig.8. 13 villages have been identified as the best suited locations for this method and categorized as good class for artificial recharge. Flooding method of recharge was constructed in 1.49 Sq.km area and 13 villages and 303.06 Sq.km area and 172 villages have been identified as medium range for this method of recharge.

Table.2 Weightage assigned in various artificial recharge methods suitable parameters

Sl. No.	Name of the method	Maps used	Weightage Assigned	No of Streams in good category	No of Villages in good category	Area (sq.km)
1	Infiltration Basin Method	Water level	(< 7.34)1 (7.34-10.75)2 (>10.75)3	54	26	218.820
		Aquifer thickness	(<41.9)1 (41.9 m -69.8)2 (>69.8)3			
		DrainageMap	-			
2	Ditch and Furrow	Slope (0 – 50)	< 100 1 5 to100 2 > 50 3	76	21	10.502
		Land use and land cover	(Other Features)1 (Land with scrub)2 (Land without Scrub)3			
		Aquifer thickness	(<41.9)1 (41.9 m -69.8)2 (>69.8)3			
		Drainage Map	-			
3	Flooding Method	Slope (0 – 50)	>30%0 5-30%0 >0- 5% 2	1.49	13	1.490
		Land use and land cover	(Other Features)1 (Land with scrub)2 (Land without Scrub)3			
		Top soil thickness m	< 1.9 1 (1.9 – 2.005) 2 (>2.005) 3			
4	Irrigation Method	Rainfall	Low 1 Medium 2 High 3	0.72	8	0.718
		Agricultural land	(Land with scrub, fallow land) 2			
		Soil permeability	(High permeability)3 (Medium permeability)2 (Low permeability)1			
5	Desilting of Existing Tanks	Aquifer thickness	(<41.9)1 (41.9 m -69.8)2 (>69.8)3	39	22	260.023
		Soil Permeability	Slow 1 Moderate 2 Rapid 3			

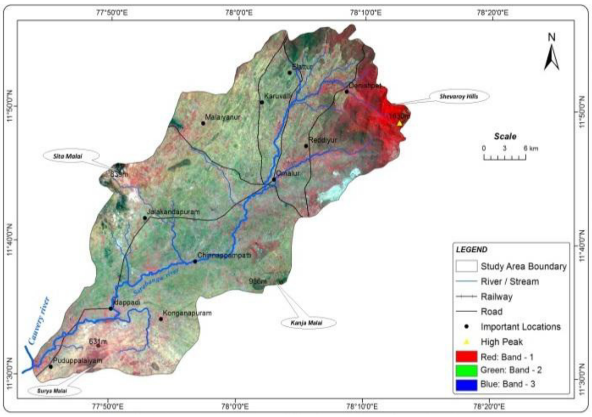

Fig.5.IRS P6 LISS IV image of the study area

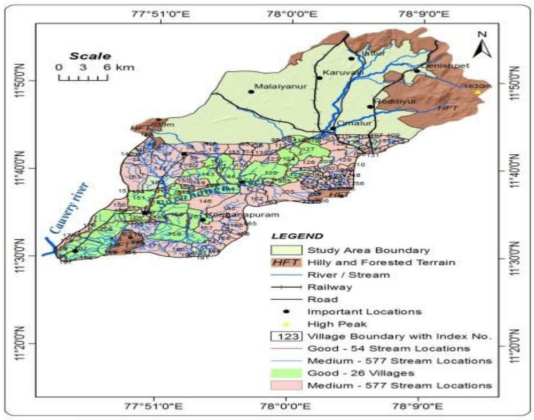

Fig.6. Feasible sites for Basin artificial recharge structure

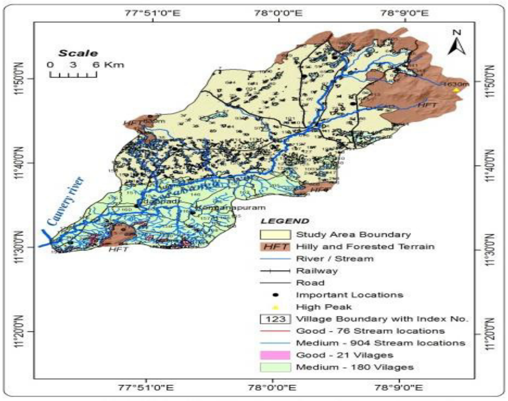

Fig.7. Feasible sites for Ditch and Furrow artificial recharge structure

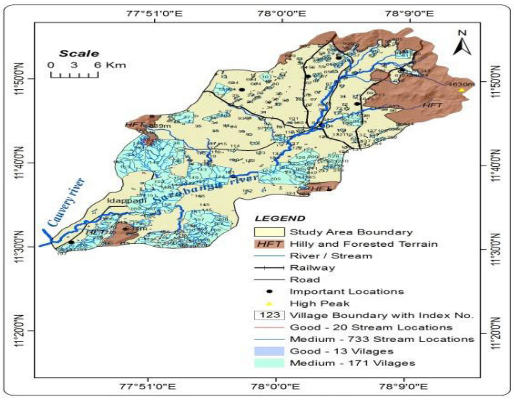

Fig.8. Feasible sites for Flooding artificial recharge structure

10.4. Irrigation Method

This method is specifically designed for paddy cultivated areas. During the preparation of the field for paddy, the soil is made impervious for water retention. Percolation of water in the paddy area is very less. This has serious effect on the recharge of aquifer in this area. A pit is constructed in the field where the slope is maximum. The level of the soak pit is slightly below the optimum level of water in the paddy field.

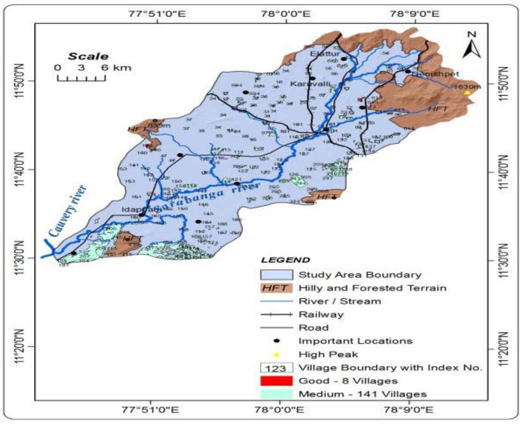

Fig.9. Feasible sites for Irrigation artificial recharge structure

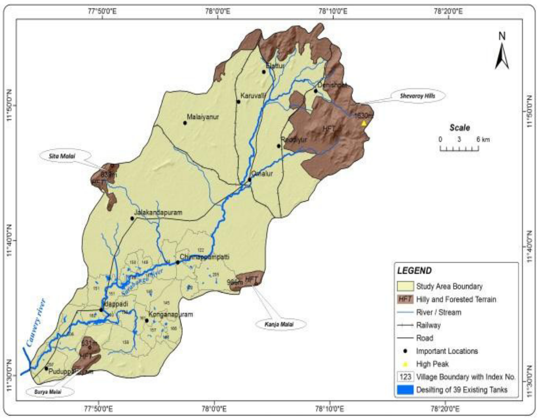

Fig.10. Feasible sites for Desilting of Existing Tanksartificial recharge structure

In this way the excess water percolates through the soak pit to the subsoil.Isohyetal map (Medium and High Rainfall), Agricultural Land (Land with Scrub and Fallow Land) and Soil Permeability map were taken for the GIS integration. The GIS output results have been given in Table 2 and village overlay map in Fig.9. 8 villages have been identified as the best suited locations for this method and categorized as good class for artificial recharge.

11.5. Desilting of Existing Tanks

The existing village tanks which are normally silted and damaged can be modified to serve as recharge structure. Most of the tanks are filled with particles like soil, vegetation and other transported materials viz., drainages and streams. This type of tanks can store minimum amount of water, therefore can remove the deposited materials. The GIS results with village integration map for site selection have been given in Table 2 and Fig.10 reveals 39 tanks which fell in 22 villages have been identified as suitable for Desilting of existing tanks. The numbers of existing tanks have been worked to remove sediments in order to store higher amount of water and in turn enhance the groundwater storage.

11. Conclusions

The investigations were carried out in accordance with updated hydrogeological methodology. Key findings have been made in GIS environment for identifying micro level village wise favorable areas amenable to different artificial recharge structures have been derived for sustainable development of groundwater resources in the Sarabanga sub basin, Cauvery river. Such advancements will certainly enable us to develop and manage precious groundwater resources in a real sustainable and environment-friendly way.

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